4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period from the beginning of construction through final repository closure, and includes project phases of construction, operation and monitoring, and closure. For purposes of analysis, the repository would remain open from 115 to 341 years from the beginning of construction to final closure, depending upon the operating mode and operating parameters selected. Chapter 5 discusses the environmental consequences of long-term repository performance—that period out to 10,000 years and beyond after repository closure. Chapter 6 discusses the environmental consequences of transportation, and Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of repository components (for example, disposal containers and drip shields) and shipping casks, and a floodplain assessment. The implementation of the Proposed Action would require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

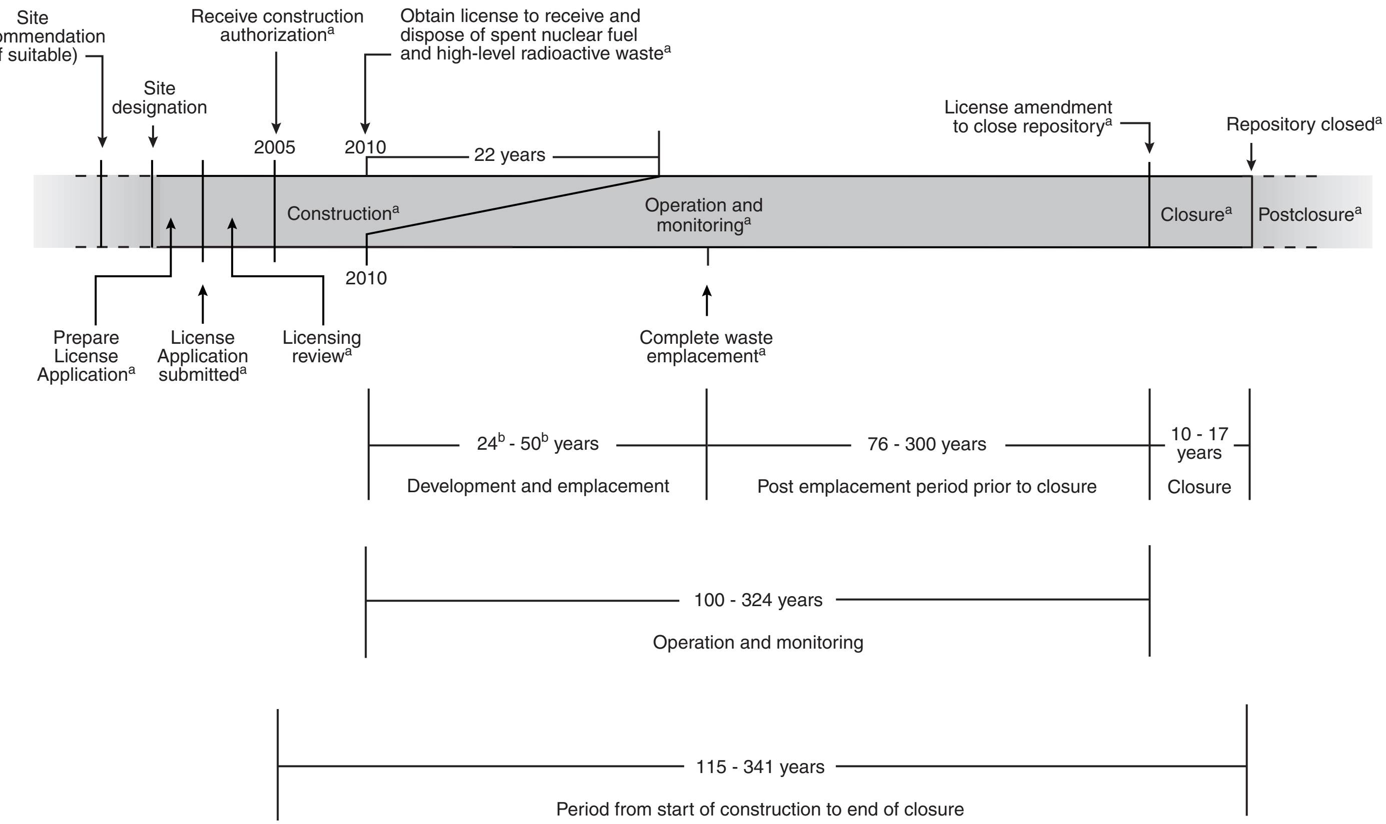
The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the operating modes evaluated in this environmental impact statement (EIS). Chapter 2 describes these operating modes in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the testing and performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION TESTING AND PERFORMANCE CONFIRMATION ACTIVITIES

The preconstruction testing and performance confirmation program would continue many of the same types of activities performed during site characterization—tests, experiments, and analyses—for as long



a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 4-1. Monitored geologic repository range of milestones used for analysis.

as required. DOE would continue performance confirmation activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after *permanent closure*.

INITIAL CONSTRUCTION PHASE (STARTING IN 2005, LASTING 5 YEARS)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. For analysis purposes, this EIS assumed construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Most surface facility construction would be completed during this phase, with the exception of the solar facility and aging pads, if built. Initial subsurface construction would excavate access mains, ventilation shafts, and the first emplacement drifts and prepare them for the start of emplacement activities, assumed for analysis purposes to begin in 2010. As mentioned above, performance testing and confirmation activities would be ongoing during this period.

OPERATION AND MONITORING PHASE

The operation and monitoring phase would last 100 to 324 years and would consist of an operations period and a monitoring period. The EIS analyses assumed that repository operations would begin in 2010, assuming DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. The operations period would include continued development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level waste in surface facilities, and emplacement of these materials in the completed portions of the subsurface repository. Development activities would last 22 years for all operating modes, concurrent with handling and emplacement. Handling and emplacement activities would last 24 years for the higher-temperature operating mode and for the lower-temperature operating mode if surface aging was not used. If surface aging was used, the operations period would last 50 years.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, the monitoring period would begin, during which monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last from 76 to 300 years. The first 3 years of the monitoring period would include the radioactive decontamination of surface facilities used for handling radioactive materials. Facilities would be decontaminated so there would be no chance for release of contamination when they were in standby mode during the monitoring period, and they would be ready for either demolition during the Closure Phase or for use as part of a retrieval contingency.

Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for the time periods evaluated in this chapter. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement for the higher-temperature operating mode, and 149 to 324 years for the lower-temperature operating mode.

As mentioned above, DOE would continue its performance confirmation activities during the development, waste emplacement, and monitoring activities.

CLOSURE PHASE (LASTING 10 TO 17 YEARS)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take 10 years for the higher-temperature operating mode and from 11 to 17 years for the lower-temperature operating mode, depending on the operating parameters that had been employed. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Backfilling the main drifts, access ramps, ventilation shafts, and connecting openings and sealing underground-to-surface openings
- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY OPERATING MODES

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a range of higher-temperature to lower-temperature operating modes for evaluation in this EIS. The higher-temperature operating mode has an established set of operating parameters (DIRS 153849-DOE 2001, all). The desired characteristics for a lower-temperature operating mode could be reached under a variety of operating parameters, and was evaluated using a range of parameter values affecting repository size and ventilation characteristics, number and spacing of waste packages, and length of activity periods. Elsewhere in this EIS (Chapter 6 and Appendix J) the potential impacts of specific transportation and fuel packaging options (Appendix F) are examined. Where transportation and spent fuel packaging options may make a difference in repository impact analysis, legal-weight truck transportation option and/or uncanistered spent fuel packaging have been assumed because they typically result in the highest potential impacts. There are a few exceptions to this general rule, for example, where use of canisters for fuel packaging would result in additional waste. These instances are specifically identified where they occur in Chapter 4.

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Preconstruction Testing and Performance Confirmation and from Land Withdrawal

Preconstruction testing and performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (7.7 square miles), current right-of-way reservations N-47748 [210 square kilometers (81 square miles)] and N-48602 [about 75 square kilometers (29 square miles)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (230 square miles) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1). Of the 600 square kilometers, approximately 210 square kilometers (81 square miles) comprise the right-of-way reservation noted above, with 180 square kilometers (70 square miles) remaining in public lands under the Bureau of Land Management's right-of-way agreement with DOE. As such, these lands are currently available for public use including mineral exploration and recreation. There are several current mining and mineral claims within the parcel that would be affected by withdrawal from public use. Such leases and unpatented mining claims could be withdrawn by the Bureau of Land Management or could be voided by an act of Congress that would withdraw the land for a repository. The current recreational use of the land under the Bureau of Land Management's right-of-way agreement could also be withdrawn by the Bureau or by establishment by Congress of a repository at Yucca Mountain.

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 6 square kilometers (1,500 acres, 2.3 square miles) composed of small noncontiguous areas within the larger 600-square-kilometer (230-square-mile) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little among repository operating modes. Most of the surface facilities and disturbed land would be in the South

Portal Development Area and North Portal Operations Area. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for the repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for repository site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would contour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

Surface disturbance for the higher-temperature operating mode would be 4.3 square kilometers (1,000 acres). Surface disturbance for the lower-temperature operating mode would range from 4.5 square kilometers (1,100 acres) to approximately 6 square kilometers (1,500 acres). The surface disturbance represents a small amount of the 600 square kilometers (150,000 acres) of land withdrawn for the repository. Therefore, there would be small impacts to land use due to the implementation of the Proposed Action.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure. Appendix G provides more details on the methods used for air quality analysis.

Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling; nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter emissions from fossil fuel consumption; and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (DIRS 103242-EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not quantitatively address the two other criteria pollutants, lead and ozone (see Appendix G, Section G.1). There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a general comparison to the pending National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), which has yet to be implemented (see Chapter 3, Section 3.1.2.1). DOE used these standards, among other air quality standards shown in Chapter 3, Section 3.1.2.1, in analyzing the nonradiological air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from DIRS 101882-NCRP (1996, Volume 1, pp. 113 and 125) to estimate doses to *noninvolved workers* (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. For periods of 1 year or longer, maximally exposed individuals were assumed to be at the southern boundary of the land withdrawal area, the closest location they would be for long periods during repository activities.

4.1.2.1 Impacts to Air Quality from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, *nitrogen oxides*, *sulfur oxides*, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone). This analysis assumed that site characterization activities are representative of preconstruction testing and performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from preconstruction testing and performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which for analysis purposes would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal Operations Area, South Portal Development Area, and ventilation shaft areas and associated access roads.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust. The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site

- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface during construction activities

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all operating modes with the exception of PM_{10}. The 24-hour PM_{10} concentrations for the range of operating modes would be about 4 to 6 percent of the regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-1. Maximum construction phase concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.40	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	[Annual[d]]	[10[d]]	0.018	0.017 - 0.018	0.18	0.17 - 0.18

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would not be greatly different under the higher- and lower-temperature operating modes during the construction phase. Differences do result for PM_{10} releases during the larger land disturbances and maintenance of the larger excavated rock piles of the lower-temperature operating modes. The construction of ventilation shafts and their access roads contributes significantly to the particulate releases. Although well within regulatory limits, particulate release rates would be further reduced by dust suppression measures taken during construction.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, p. 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1.2, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles rapidly deposit on the surface (DIRS 103243-EPA 1996, p. 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.02 microgram per cubic meter or less for the various operating modes, or less than 0.2 (0.18) percent of the benchmark. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust, and hence cristobalite, from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Chapter 3, Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, a process called radon emanation. Once in the repository drifts the radon and decay products would be exhausted as part of repository ventilation. DOE based potential future releases of radon-222 on modeled estimates of radon flux, concentration, and release in the repository (DIRS 154176-CRWMS M&O 2000, all). These estimates were generated using observed radon concentrations in the Exploratory Studies Facility (DIRS 150246-CRWMS M&O 2000, Attachment X) and considering the repository structure and ventilation characteristics, particularly the ventilation pressure differentials. Total estimated radon releases during the 5-year construction phase would be very similar for the range of repository operating modes. These releases, and the potential doses that resulted from them, would be similar because the size and structure of the excavated repository and the repository ventilation would be similar under each mode during the construction phase. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be about 1.7 to 2.0 millirem for the 5-year initial construction phase under the flexible design repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be no more than about 0.53 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3.5 percent of this standard. The offsite population dose would be 33 to 40 person-rem. The maximum annual dose to the maximally exposed noninvolved repository worker would be about 1.9 to 2.3 millirem during the initial construction phase. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all the repository workers on the surface. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air *pathway* would be less than 0.5 (0.48) person-rem during this phase (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and 5-year construction phase doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Radiation doses to maximally exposed individuals and populations during initial construction phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[d] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[f] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039

a. Numbers are rounded to two significant figures.
b. Annual values are for the maximum year during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Development Area.
f. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Operation and Monitoring

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository. For analysis purposes, this phase would begin in 2010 for both repository operating modes; it would last for 100 years for the higher-temperature operating mode and from 149 to 324 years for the lower-temperature operating mode. Activities during this phase would include the continued excavation of subsurface drifts (beginning in 2010 and lasting 22 years), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (beginning in 2010 and lasting 24 years), and the emplacement of disposal containers in the repository (beginning in 2010 and lasting 24 years without aging or 50 years with aging). These activities would take place concurrently. After the emplacement of all spent nuclear fuel, monitoring of the disposal containers and maintenance of repository facilities would last from 76 to 300 years.

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities beginning at 2010, when handling and continued subsurface development and emplacement activities would occur simultaneously. This phase could last from 100 to 324 years, depending on the operating mode and design. Continued development of the subsurface facilities would last 22 years for all operating modes. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the excavation, placement, and maintenance of rock at a surface storage pile
- Fugitive dust emissions from continued construction of the aging pads, if used to achieve lower-temperature operations
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation during construction and emplacement
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the operating modes. The lower-temperature operating mode would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance.

Table 4-3 lists estimated maximum concentrations at the land withdrawal area boundary for the higher- and lower-temperature operating modes.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For the range of operating modes, the public maximally exposed individual would be exposed to less than 2 (1.6) percent of the applicable regulatory limits. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the land withdrawal area boundary. As discussed for the initial construction phase (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The

Table 4-3. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during the operation and monitoring phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[d]	10[d]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated exposures to cristobalite from repository operations would be small, about 0.017 microgram per cubic meter or less for the range of operating modes, or less than 0.2 (0.17) percent of the benchmark.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be comparable in the construction and operation and monitoring phases. Concentrations of gaseous criteria pollutants would decrease during emplacement and development activities because vehicle emissions would decrease during emplacement and development. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities lasting 76 to 300 years at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

The flexible design repository operating modes would remove at least 70 percent of the heat generated by the spent nuclear fuel inventory during the preclosure period (DIRS 153849-DOE 2001, p. 2-15). The peak ventilation air temperature for the higher-temperature operating mode would be 58ºC (136ºF) for 1.4-kilowatt-per-meter linear thermal load, occurring 10 years into the preclosure period and decreasing thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). The higher-temperature operating mode has the highest linear thermal load (DIRS 153849-DOE 2001, p. 2-24) and would have the highest exhaust air temperatures. This air temperature would be lower than the exhaust air temperature of many other industrial processes such as powerplants, manufacturing facilities, and incinerators. Impacts from the heat released in ventilation air would be unlikely on either the climate or ecosystems of the area.

4.1.2.3.2 *Radiological Impacts to Air Quality from Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase. Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue. If surface aging was used, the initial 24 years of operations would be followed by 26 years of emplacing commercial spent nuclear fuel from the aging facility. Aging would result in a 50-year operations period rather than the 24-year period without aging.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities for 76 to 300 years. During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Operations Period. The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (DIRS 101893-NRC 1979, p. 4-10). Approximately 2,600 curies would be released annually (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 5.9×10^{-2} curie of radon-220, and 4.6×10^{-6} curie of radon-222 (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger repository size, with more surface area for radon flux from the repository walls and greater quantities exhausted by ventilation. The effect of waste packages heating the walls of the emplacement drifts, which would slightly increase the radon flux, was also considered (DIRS 154176-CRWMS M&O 2000, p. 10). The estimated differences in radon releases would be a function primarily of the waste package spacing, which would affect the total repository size, and of the duration of the monitoring period. In general, a larger waste package spacing distance would lead to a larger repository, which would result in more radon released per year and a shorter ventilation period. Annual releases, therefore, would be higher but total releases would be lower. Appendix G, Section G.2.3.1, contains more information on estimates of radon release for the range of operating modes. Activation of the air around waste packages would result in the creation of a small quantity of radioactive noble gases. These noble gases would contribute negligibly to the dose from the air pathway (DIRS 139546-CRWMS M&O 2000, all).

Table 4-4 lists estimated annual doses and doses during the handling and emplacement period to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. As for the other project phases, naturally occurring radon-222 and its decay products released in subsurface ventilation air would be the major dose contributors from airborne releases. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be a small component of the overall dose, contributing less than 0.01 percent of the dose to the public and typically less than 1 percent of the dose to noninvolved workers for the operations period. The principal exception would be the dose to the noninvolved worker population at the Nevada Test Site, where the krypton-85 contribution to dose would be as high as 3.5 percent of the total dose. Appendix G, Section G.2.3.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-4. Radiation doses for maximally exposed individuals and populations during the operations period.[a,b]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
Offsite MEI[d] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[e] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[g] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012

a. Numbers are rounded to two significant figures.
b. Fuel handling activities would last 24 years. Emplacement activities would last 24 years with no aging or 50 years with aging. Continuing subsurface development activities would last 22 years.
c. Maximum annual dose would occur during the last year of development, when the repository had reached its largest and DOE still used the South Portal for exhaust ventilation.
d. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The dose to the offsite maximally exposed individual would be 12 to 20 millirem during the 24 years of operations, increasing to 43 millirem for the additional 26 years of operations if DOE used aging. The maximum annual dose to the offsite maximally exposed individual would be about 0.73 to 1.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 5 to 9 percent of this standard. The population dose would be 230 to 390 person-rem for 24 years of operations, increasing to 830 person-rem for the additional 26 years of operations with aging. Essentially the entire dose would be from naturally occurring radon-222 released from the subsurface in ventilation air. Releases of radioactive noble gases from surface facilities (Waste Handling and Waste Treatment Buildings) during spent nuclear fuel handling would make very small differences in the dose received. Aging would increase the operations period by 26 years, but also would decrease the monitoring period by 26 years, so the total impact would be unchanged.

The dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 30 to 42 millirem during the 24 years of handling and emplacement activities, increasing less than 0.2 millirem for the additional 26 years of operations for aging. The increase would be small because DOE would stop using the South Portal for exhaust ventilation at the completion of development, and exhaust from the ventilation shafts would result in much less dose to the maximally exposed worker. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers annually (a total of 31,000 to 32,000 worker-years for 24 years of operations). This total would increase to about 50,000 surface worker-years for the 50 years of operations needed for aging. In addition, an estimated 1,500 to 2,100 total subsurface worker-years would be needed on the surface at the South Portal Development Area (see Appendix G, Table G-49). The noninvolved worker population dose would range from 1.2 to 1.8 person-rem over the 24-year emplacement period, increasing slightly to 1.9 person-rem considering the additional 26 years of the operations period needed for aging. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal during development activities, would receive most of the population dose from airborne releases. However, the bulk of worker radiation dose comes not from airborne releases but from more direct occupational exposure. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring Period. Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would require a larger number of noninvolved workers. These workers would be exposed to naturally occurring radon ventilated from the subsurface. Decontamination of the surface facilities would result in no or negligible airborne releases of radionuclides because of the low levels of contamination present, high-efficiency particulate air filters on the air exhausts, and modern facility design and decontamination techniques that would minimize the potential for airborne contamination. After the completion of decontamination, most of the noninvolved workers would no longer be employed, resulting in a much lower noninvolved worker population and correspondingly lower worker population dose.

Monitoring periods would range from 76 to 300 years depending on the repository operating mode and selected operating parameters. Table 4-5 lists estimated maximum annual doses and total doses that would occur from monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be 29 to 62 millirem during monitoring and maintenance activities for the range of repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be about 0.41 to 0.89 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

The population dose for monitoring and maintenance activities would range from 600 to 3,500 person-rem, the difference mainly reflecting the range of 76 to 300 years of postemplacement monitoring. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal Development Area, would range from 0.096 to 0.33 millirem for a 50-year working lifetime during monitoring and maintenance activities. The dose to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would range from 0.0091 to 0.05 person-rem for the monitoring period.

In general, longer periods of monitoring and maintenance activities would result in larger total releases of radon and its decay products and potentially extend these impacts to future generations of workers and the public. Highest total doses during the monitoring period for the 80-kilometer (50-mile) population and the Nevada Test Site noninvolved worker population would be under conditions of maximum ventilation and moderate waste package spacing, which would require the longest time (300 years) of ventilation and monitoring. For the other potential doses listed in Table 4-5, the highest potential total and annual doses for monitoring would be under conditions of largest waste package spacing, which would require the largest repository and have the largest radon release per year from the repository. Section 4.1.7 discusses human health impacts to the public and workers from the monitoring period.

Table 4-5. Radiation doses to maximally exposed individuals and populations during the monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[d] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population (person-rem)	0.0091	0.0013[f]	0.031 - 0.05	0.000034 - 0.0057[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.033	0.00044	0.083 - 0.19	0.00021 - 0.00094

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of monitoring, which would last from 76 to 300 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area. Values are for a 70-year lifetime.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area. Values are for a 50-year onsite working lifetime.
f. Maximum annual dose occurs during the 3 years of decontamination activities when worker population is largest.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.4 Impacts to Air Quality from Closure

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin after the 76 to 300 years of monitoring and last 10 to 17 years. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing, and transfer of backfill material to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) and particulate matter from fuel consumption
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land

- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the higher- and lower-temperature operating modes.

Table 4-6. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.7	3.4 - 3.6
Cristobalite	Annual[d]	10[d]	0.012	0.0089 - 0.0098	0.12	0.089 - 0.098

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Gaseous criteria pollutants would result primarily from vehicle exhaust. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 4 percent of the regulatory limit for all operating modes. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. Table 4-6 lists estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.01 microgram per cubic meter or less for all three thermal load scenarios, or less than one-tenth of 1 percent (0.098) of the benchmark. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 10 to 17 years. Exposure to the noninvolved (surface) worker population would occur during the 6-year period while this group was working on surface facility closure. Exposure would continue to members of the public and a smaller number of workers throughout the period for subsurface facility closure.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual would be 3 to 9.4 millirem for the closure phase. The maximum annual dose to the offsite maximally exposed individual would be about 0.4 to 0.87 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The population dose would be 57 to 180 person-rem for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.014 to 0.07 millirem for the entire closure phase. The dose to the noninvolved repository (surface) worker population would range from 0.004 to 0.015 person-rem. Highest doses for this phase—both total and annual—would be under conditions of largest waste package spacing, which would require the largest repository and the longest time (17 years) to close the repository.

Table 4-7. Radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
MEI[c] (millirem)	3	0.4	4.3 - 9.4	0.57 - 0.87
80-kilometer population[d] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.014	0.0018	0.024 - 0.07	0.003 - 0.0063
Yucca Mountain noninvolved worker population (person-rem)	0.004	0.00052	0.007 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[f] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089

a. Numbers are rounded to two significant figures.
b. The closure phase would begin after the 76 to 300 years of monitoring and last 10 to 17 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.5 Total Impacts to Air Quality from All Phases

The nonradiological air quality analysis examined concentrations of criteria pollutants in comparison to National Ambient Air Quality Standards. These standards are for periods ranging from 1 hour up to an annual average concentration of pollutant, so a "total" project impact is presented as no more than the highest single year. The highest concentrations of all criteria pollutants except PM_{10} would be less than 1 percent of applicable standards in all cases. PM_{10} would also be less than 1 percent of the applicable limits except: it would be less than 2 percent of the annual limit and 6 percent of the 24-hour limit during the construction phase; less than 2 percent of the 24-hour limit during the operation and monitoring phase; and less than 4 percent of the 24-hour limit during the closure phase.

The radiological impacts to air quality for the entire project are quantified by evaluating the doses to the populations of potentially exposed workers and members of the public. Results are not presented for impacts to individuals because the project duration (from 115 to 341 years) would be longer than the 70-year lifetime used for analysis purposes. Individual impacts for the various project activity periods (as long as 50 years for workers and 70 years for the public for the longer monitoring period) are discussed in the previous sections.

Table 4-8 lists total radiological air quality impacts for the entire Yucca Mountain Repository project. This table includes impacts for the higher-temperature repository operating mode and the range of impacts for the lower-temperature operating mode. The higher-temperature operating mode would have lower radiological air quality impacts, because it would have the shortest project duration (115 years), smallest excavated repository volume and therefore lowest releases of naturally occurring radon-222 and decay products, the primary dose contributor.

Table 4-8. Total radiation doses to exposed individuals and populations for all phases.[a,b,c]

	Operating mode			
	Higher-temperature		Lower-temperature[d]	
Release	Entire project	Annual	Entire project	Annual
Dose to public				
MEI[e] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population[f] (person-rem)	930	14	1,900 - 3,900	20 - 26
Dose to noninvolved workers (person-rem)				
Maximally exposed noninvolved worker[e] (millirem)	30	2	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker[g] population	1.7	0.1	1.7 - 2.4	0.12 - 0.13
Nevada Test Site noninvolved worker population[h]	0.048	0.00063	0.1 - 0.21	0.0009 - 0.0012

a. Numbers are rounded to two significant figures.
b. The duration of all project phases (construction, operation and monitoring, and closure) would range from 115 to 341 years.
c. Section 4.1.7.5.3 describes radiological health impacts.
d. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
e. MEI = maximally exposed individual. The public MEI would be exposed 70 years and the noninvolved worker MEI exposed 50 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. For air quality impacts, noninvolved workers include those at the repository surface who could be exposed to releases of radon-222 and its decay products from the exhaust shafts.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

4.1.3.1 Impacts to Hydrology from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The preconstruction testing and performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-16). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the

Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction phase, and during the operations period that would follow (lasting 24 years or 50 years if surface aging was used), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DIRS 102547-CRWMS M&O 1997, pp. 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization has not caused water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (DIRS 100147-Flint, Hevesi, and Flint 1996, pp. 57 to 59) show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operations period while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Development Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-9 lists discharge estimates to the South Portal evaporation pond for the higher- and lower-temperature operating modes. During the operations period, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. Annual discharges under the lower-temperature operating mode would increase in comparison to those from the higher-temperature operating mode because of increased waste package spacing and the associated increase in drift excavation. DOE would investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. In addition, water collected from the emplacement side of the subsurface area, if any, would be pumped to this pond after verification that it was not contaminated. Table 4-10 lists the estimated discharges to the North Portal evaporation pond for the operating modes during the operations period. The estimates of annual discharge would change under the lower-temperature operating mode depending on the specific operating parameters used. These changes would be due primarily to a small change in the estimated size (total floor space) of the facilities.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (DIRS 102303-CRWMS M&O 1998, p. 16). The North Portal evaporation pond, which would be primarily for cooling and heating process water, would, at a minimum, have a polyvinyl

Table 4-9. Annual water discharges to South Portal evaporation pond.[a,b]

Phase	Operating mode	
	Higher-temperature[a,b]	Lower-temperature[a,c]
Construction		
Discharge (cubic meters)[d]	6,800	8,500 - 9,000
Duration (years)	5	5
Operations period		
Discharge (cubic meters)	3,500	4,400 - 7,500
Duration (years)	22[e]	22[e]

a. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
b. Source: DIRS 150941-CRWMS M&O (2000, pp. 6-7 and 6-12).
c. Source: DIRS 155515-Williams (2001, pp. 13 and 17; Parts 1 and 2, pp. 5 and 9).
d. To convert cubic meters to gallons, multiply by 264.18.
e. Discharge to this pond is during subsurface development activities only.

chloride liner (DIRS 102303-CRWMS M&O 1998, pp. 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. DOE would build a third, much smaller evaporation pond, as appropriate, at the concrete batch plant to facilitate collection and management of equipment rinse water. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Table 4-10. Annual water discharges to North Portal evaporation pond during operations period.

Factor	Operating mode	
	Higher-temperature[a]	Lower-temperature[a,b]
Discharge (cubic meters)[c]	34,000	31,000 - 36,000
Duration (years)	24	24

a. Source: DIRS 152010-CRWMS M&O (2000, p. 52).
b. Source: DIRS 155516-Williams (2001, p. 4)
c. To convert cubic meters to gallons, multiply by 264.18.

Other uses of water during the operations period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface during the monitoring period and from closure would be similar to or less than those discussed for the initial construction phase and operations period. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A*, General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Radiologically Controlled Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Radiologically Controlled Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (DIRS 102303-CRWMS M&O 1998, pp. 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. Inundation levels expected from a 100-year, 500-year, regional maximum, or even probable maximum flood would represent no hazard to the proposed repository subsurface facilities, the portals of which would be at higher elevations than the flood-prone areas (DIRS 151945-CRWMS M&O 2000, p. 7.3-4 and Figure 7.3-3).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Radiologically Controlled Area and one for the balance-of-plant facilities. The basin for the Radiologically Controlled Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Fuel oil storage tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [up to about 1,300 liters (330 gallons) per year] (DIRS 152010-CRWMS M&O 2000, p. 51). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Radiologically Controlled Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the operation and monitoring phase would be managed in the Radiologically Controlled Area of the North Portal Operations Area. This would include the Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast, and the aging pads if used for the lower-temperature operating mode. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components. If a lower-temperature operating mode with surface aging was implemented, the fuel blending pools (total capacity of 5,000 MTHM) would be eliminated from the design. A fuel transfer pool associated with the assembly transfer system would still be present, but would represent a much smaller volume of water. Elimination of the blending pools would eliminate a source of potential water releases, but in all cases the probability of leakage from any of these pools would be very low, given current design engineering, and construction standards and the importance of leak prevention.

During the operation and monitoring phase a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DIRS 101779-DOE 1998, Volume 2, p. 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2.8 square kilometers (690 acres) of land would be disturbed during the construction and operation and monitoring phases of the higher-temperature operating mode. Including land already disturbed during the characterization activities, the total would be about 4.3 square kilometers (1,060 acres). The amount of newly disturbed land would be about 4.0 to 4.5 square kilometers (990 to 1,100 acres) under the lower-temperature operating mode. Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, almost all of the area that would be disturbed at the proposed repository site is drained by Drill Hole Wash, which includes Midway Valley Wash as a major tributary. The maximum new disturbance of 4.5 square kilometers (1,100 acres) would be small (less than 12 percent) in comparison to the approximate 40 square kilometers (9,900 acres) that comprise the drainage area of Drill Hole Wash by the time it reaches Fortymile Wash (DIRS 102783-Squires and Young 1984, p. 2).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

Repository-related structures could affect small drainage channels or washes. DOE expects to control surface-water drainage in these washes with minor diversion channels, culverts, or similar drainage control measures. Some transportation-related construction, operation, and maintenance actions would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the repository project, which would include construction, operation and monitoring, and closure. Chapter 5 describes potential impacts as a result of the repository's long-term performance after closure. The following impacts would be of primary concern while the repository was open:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer

- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones

- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (DIRS 151945-CRWMS M&O 2000, p. 8.9-8), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the South Portal Development Area and North Portal Operations Area, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DIRS 102197-CRWMS 1997, all). This careful use of water in the subsurface would continue during additional repository excavation. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be of small impact to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants. Chapter 5 discusses the long-term postclosure release of contaminants from the waste packages emplaced in the repository.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction phase and the operation and monitoring phase. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-11 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the operating mode employed. The lower-temperature operating mode would involve emplacement of less spent fuel per unit of repository footprint area, which correlates with increased excavation and increased water to support that excavation.

Table 4-11. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Duration (years)	Water demand (acre-feet per year)[a]	
		Higher-temperature	Lower-temperature
Construction	5	160	190 - 210
Operation and monitoring			
Operations period[b]			
Emplacement and development	22	230	250 - 290
Subsequent emplacement only	2 or 28	180	90 - 190
Monitoring period			
Initial decontamination	3	220	200 - 230
Subsequent monitoring and caretaking	73 - 300	6	3 - 6
Closure	10 - 17	81	70 - 84

a. To convert acre-feet to cubic meters, multiply by 1,233.49. Acre-feet are presented because of common public knowledge of this area.

b. Development of the subsurface area would last 22 years for the Proposed Action and emplacement would continue another 2 years without aging. If aging was included, emplacement would not be completed until 28 years beyond the completion of development.

As listed in Table 4-11, water demand during the initial construction phase would range from about 200,000 to 260,000 cubic meters (160 to 210 acre-feet) per year under the range of operating modes. Water demand during the operations period would also vary by operating mode and could range from about 280,000 to 360,000 cubic meters (230 to 290 acre-feet) per year. Once subsurface development was complete and only emplacement was occurring, the estimated annual water demand would range from 110,000 to 230,000 cubic meters (90 to 190 acre-feet). The low end of this range would occur only if the aging facility was included, but it would last for about 26 years while the spent nuclear fuel on the surface pad completed its 30-year cooldown period and DOE gradually moved it to the subsurface. The first 3 years of the monitoring period would include facility decontamination efforts and would require water at a rate varying from 250,000 to 280,000 cubic meters (200 to 230 acre-feet) per year. After the first 3 years, water demand would drop substantially to estimated levels of only 3,700 to 7,400 cubic meters (3 to 6 acre-feet) for the duration of the monitoring period. The closure phase would require about 86,000 to 100,000 cubic meters (70 to 84 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by three methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water
- Groundwater modeling efforts to assess any changes the proposed demand would have on groundwater elevations and flow patterns

Groundwater Demand During Construction

During the initial construction phase, the estimated water demand from the Jackass Flats hydrographic area would be about 540,000 to about 600,000 cubic meters (440 to 490 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6)]. This quantity is very similar to the roughly 490,000 cubic meters (400 acre-feet) withdrawn from the Jackass Flats area in 1996 (see Chapter 3, Table 3-16). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-17), during which elevation decreases as large as 6 to 12 centimeters (2.4 to 4.7 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

Effect of Operations on Groundwater Perennial Yield

As the Proposed Action would move from construction into the operation and monitoring phase, groundwater withdrawal rates would increase. The following discussion of impacts centers on comparisons to the perennial yield of the groundwater basin supplying the water.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (DIRS 104954-Thiel 1997, p. 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 370,000 cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 720,000 cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 720,000 cubic meters (580 acre-feet). The highest estimated water demand during the operation and monitoring phase would not exceed this lowest estimate of perennial yield, and it would represent only about 7 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (DIRS 105034-Turnipseed 1992, pp. 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 720,000 cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 720,000 cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 720,000 cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be small.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction phase would be about 600,000 cubic meters (490 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [720,000 cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. Maximum repository water demands would occur during the operations period (Table 4-11), which when combined with the baseline demands from Nevada Test Site activities would approach but still be below the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek groundwater basin, the heaviest water demand is in the Amargosa Desert. Over the period of the repository project's need for water, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (DIRS 103099-Buqo 1999, pp. 37, 38, and 52). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 600,000 cubic meters (490 acre-feet) a year] and the operation and monitoring phase [about 700,000 cubic meters (570 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Potential Changes to Groundwater Elevation

Two separate modeling efforts have assessed potential changes to groundwater elevations and flow patterns as a result of water demands from the proposed repository action. One study (DIRS 145966-

CRWMS M&O 2000, all) was performed by Thiel Engineering Consultants for DOE; the other study (DIRS 145962-Tucci and Faunt 1999, all) was performed by the U.S. Geological Survey. Both efforts included the modeling of baseline conditions that included historical water withdrawals from the Jackass Flats area followed by modeling of future water withdrawals that include the baseline and an additional annual water demand of 530,000 cubic meters (430 acre-feet) for the proposed repository. The studies focused on the predicted differences between the baseline and future simulations in the groundwater flow regime of Jackass Flats and surrounding hydrographic areas, particularly the Amargosa Desert (see Figure 3-17). The Thiel Engineering Consultants study included the use of transient models (DIRS 145966-CRWMS M&O 2000, p. 2) to project changes in groundwater levels and flow patterns. It utilized several different assumed groundwater withdrawal scenarios over this area, with and without the water demand for the repository project, and simulated the withdrawal scenarios for 100 years. The U.S. Geological Survey effort compared the results of two steady-state simulations (baseline and predictive future) of the regional groundwater flow system. Results of the simulations indicated that there would be groundwater elevation differences (between conditions with and without the Proposed Action) as described in the following summary statements:

- The Thiel Engineering Consultants study predicted a water elevation decrease of up to 3 meters (10 feet) within about 1 kilometer (0.6 mile) of the Yucca Mountain production wells as a result of the Proposed Action's water demand (DIRS 145966-CRWMS M&O 2000, p. 86). The U.S. Geological Survey model resulted in similar projections, predicting a water level decrease of less than 2 meters (6.6 feet) at distances of a few kilometers from the production wells (DIRS 145962-Tucci and Faunt 1999, p. 13).

- The models predicted water elevation decreases at the town of Amargosa Valley ranging from less than 0.4 meter (1.2 feet) (DIRS 145966-CRWMS M&O 2000, all) to 1.1 meters (3.6 feet) (DIRS 145962-Tucci and Faunt 1999, p. 13).

- Both models generated predictions of the reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area that would result from the Proposed Action. The Thiel Engineering Consultants (DIRS 145966-CRWMS M&O 2000, p. 89) study estimates a flow reduction of about 160,000 cubic meters (130 acre-feet) per year after 100 years of pumping. The U.S. Geological Survey (DIRS 145962-Tucci and Faunt 1999, p. 13) effort estimates 180,000 cubic meters (150 acre-feet) per year at steady-state conditions.

The Thiel Engineering Consultants modeling effort looked at numerous locations and pumping scenarios throughout the groundwater region. The results indicated that in all areas of the Amargosa Desert, the decreases in groundwater elevation attributed to the Proposed Action would be minor in comparison to those simulated for the areas without the Proposed Action (DIRS 145966-CRWMS M&O 2000, pp. 173 to 184). Both models evaluated a hypothetical Yucca Mountain Project water demand of 530,000 cubic meters (430 acre-feet) per year, which is the quantity planned for the site's application for a water appropriation. As listed in Table 4-11, the highest estimate of the Proposed Action's annual water demand is only about 67 percent of this quantity. Had this smaller number been used in the models, a corresponding decrease in the predicted effects would have resulted. The Proposed Action's higher periods of water demand [that is, periods with annual water demand near or above 250,000 cubic meters (200 acre-feet)] would total only about 30 years compared to the 100 years of demand at the higher rate used in the Thiel Engineering Consultants study.

Monitoring Period

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities, which would take place during the first 3 years of the monitoring period. Routine monitoring and maintenance activities would involve minimal water needs.

Closure Phase

The annual demand during closure would vary by a small amount based on the operating mode used, but would be less than 30 percent of the maximum demand during the operation and monitoring phase and, similarly, would have minor impacts on groundwater resources.

Summary of Impacts to Hydrology

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.
- The potential for flooding at the repository site is extremely small.
- Water demand under highest consumption conditions would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. The highest demand conditions in combination with ongoing Nevada Test Site demand from the same basin would also be below the lowest estimates of perennial yield.
- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Valley in comparison to the quantities of water already being withdrawn there.

DOE filed an application for permanent water rights with the State of Nevada for the projected water needs to meet DOE's responsibilities under the NWPA. Uses for the water would include, but not be limited to, road construction, facility construction, drilling, dust suppression, drift and pad construction, testing, culinary, domestic, and other related site uses. On February 2, 2000, the Nevada State Engineer denied the application on the basis that the proposed use threatens to prove detrimental to the public interest because the proposed use (that is, supporting the repository action) is prohibited by existing State law. On March 2, 2000, DOE filed an appeal of the State Engineer's decision (DIRS 151945-CRWMS M&O 2000, pp. 9.5-5 and 9.5-6). On October 15, 2001, the U.S. Court of Appeals (9th Circuit) remanded the case back to the Nevada District Court for a hearing on the merits. At the time this EIS was prepared, the appeal was still in process and a final outcome for the water appropriation application had not been determined.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from preconstruction testing and performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

Impacts to desert tortoises from preconstruction testing and performance confirmation would be less than impacts that occurred during site characterization, during which five tortoises have been killed on roads at Yucca Mountain (DIRS 104593-CRWMS M&O 1999, p. 3-12). Habitat loss during the peak of site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). Because the desert tortoise is a *threatened species*, it would continue to receive special consideration during land-disturbing activities. DOE would continue to work with the U.S. Fish and Wildlife Service and would implement the terms and conditions required by the Service to minimize impacts to desert tortoises at the site (see Appendix O). Thus, preconstruction testing and performance confirmation would have very little or no impact on the desert tortoise population at Yucca Mountain or along roads traveled to the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist mainly of naturally occurring radon-222 and its decay products (see Section 4.1.2 and Appendix G, Section G.2). These releases would result in very small doses to plants and animals around the repository. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). The International

Atomic Energy Agency has concluded that chronic dose rates less than 100 *millirad* per day to plants and animals are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53). Expected dose rates to plants and animals would be much less than 100 millirad per day. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary among the repository operating modes (Table 4-12).

Table 4-12. Land cover types in the land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

Land cover type[c]	Area in Nevada	Land withdrawal area	Area that would be disturbed: Higher-temperature	Area that would be disturbed: Lower- temperature
Blackbrush	9,900	140	0.0	0.0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0.0
Salt desert scrub	58,000	20	0.0	0.0
Previously disturbed	NA[d]	4	1.5	1.5
Totals[e]	***NA***	***600***	***4.3***	***4.5 - 6.0***

a. Source: Derived from facility diagrams from DIRS 104523-CRWMS M&O (1999, all) and land cover types maps and vegetation associations (DIRS 102303-CRWMS M&O 1998, all) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the piñon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. NA = not applicable.
e. Totals might differ from sums due to rounding.

Five of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-12). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-12). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in previously disturbed areas or areas dominated by creosote-bursage and Mojave mixed scrub.

Repository construction activities in undisturbed vegetation could result in additional areas where colonization by exotic plant species could occur. Exotic species that are currently present on the site (see Section 3.1.5.1.1) would be the most likely *invasive species*. *Native species* could be suppressed in areas colonized by exotic species and there could be an increase in fire fuel load associated with dried annual plant species. Because the undisturbed vegetated area that would be disturbed by construction is small compared to the total undisturbed vegetated area, impacts to native species and the threat of increased fires would also be small.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area.

Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North Portal Operations Area and South Portal Development Area. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (DIRS 103075-Bechtel 1997, p. 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 U.S.C. 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (DIRS 102869-CRWMS M&O 1997, pp. 6 to 12; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (DIRS 103194-CRWMS M&O 1998, pp. 3 to 17; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). All but one of the 28 individual relocations and both nest relocations were successful. Five tortoises (including the one unsuccessful relocation) have been killed as a result of site characterization activities; all were killed by vehicles on roads (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases.

Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect the long-term survival of the local or regional population of this species. Yucca Mountain is surrounded to the east, south, and west by large tracts of undisturbed tortoise habitat on government property, and desert tortoises are widespread at low densities throughout this region. Habitat loss caused by transportation and other activities during site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). In addition, the abundance of ravens at Yucca Mountain did not increase as a result of site characterization activities (DIRS 102236-CRWMS M&O 1998, pp. 9 through 12), and ravens were not an important cause of mortality of small tortoises during that period (DIRS 103195-CRWMS M&O 1998, p. 8).

The U.S. Fish and Wildlife Service has concluded that tortoise populations are depleted for more than a kilometer on either side of heavily used roads (DIRS 102475-Brussard et al. 1994, p. D12). The increase in traffic to Yucca Mountain (see Appendix J, Section J.3.6) would contribute to the continued depression of populations immediately adjacent to U.S. Highway 95, but would not increase the threat to the long-term survival of desert tortoise populations in southern Nevada.

As required by Section 7 of the Endangered Species Act, DOE has completed consultations with the Fish and Wildlife Service concerning the effects of repository construction, operation and monitoring, and closure on the desert tortoise. The U.S. Fish and Wildlife Service has issued a Biological Opinion establishing reasonable and prudent measures and terms and conditions to ensure that implementation of the Proposed Action would not jeopardize the desert tortoise (see Appendix O). The Biological Opinion also contains an incidental take permit. DOE would implement all the measures and terms and conditions of the Biological Opinion to protect the desert tortoise around Yucca Mountain.

The bald eagle and peregrine falcon have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected. Bald eagles are classified as threatened under the Endangered Species Act. The State of Nevada classifies the bald eagle and the peregrine falcon as endangered.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, or low, as listed and described in Table 4-13.

Table 4-13. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 4.5 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 4.5 square kilometers = 1,100 acres (6.0 square kilometers total area, including areas previously disturbed by site characterization).

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- *Soil recovery* from disturbances
- Potential for spreading contamination by relocating contaminated soils (if present)

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removed vegetation or otherwise broke up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities during the construction and operation and monitoring phases would disturb varying amounts of land depending on the operating mode used for the repository. Most of the variation would be due to the emplaced waste being spaced further apart under the lower-temperature operating mode, resulting in more excavated rock being stored on the surface and more ventilation shafts extending from the repository to the surface. A decision to incorporate an aging facility would increase the amount of land disturbed. The highest estimate of newly disturbed land as a result of the Proposed Action is about 4.5 square kilometers (1,100 acres).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (DIRS 154386-YMP 2001, p. 1). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during any phase of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DIRS 104837-DOE 1989, pp. 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DIRS 104837-DOE 1989, all; DIRS 102188-YMP 1995, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DIRS 104837-DOE 1989, p. 17; DIRS 102188-YMP 1995, p. 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

Contamination

Based on preconstruction testing and characterization activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Preconstruction Testing and Performance Confirmation

Land disturbances associated with preconstruction testing and performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region of influence (see Chapter 3, Table 3-1). Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if practical or, if it was not practical, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.